Report Prepared for the Research Division
Royal Commission on National Passenger Transportation

Analysis of National Highway System Proposals

ADI Limited
January 1992

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Opinions expressed are those of the authors and not necessarily those of the Royal Commission on National Passenger Transportation.

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report

FINAL REPORT

ANALYSIS OF NATIONAL HIGHWAY SYSTEM PROPOSALS

Prepared for:

The Royal Commission on
National Passenger
Transportation

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1.0 INTRODUCTION

1.1 Background

In 1989 ADI Limited prepared a report for the National Highway Policy Study Committee titled "National Highway Policy User Benefits". The report summarized the benefits to users of the National Highway System which would result from improvements carried out to meet minimum design and operational standards. The minimum standards proposed under the National Highway Policy (NHP) are summarized in Appendix B to this report and generally include minimum standards for geometric design, bridges, overpasses and other design and control elements.

Time saving, vehicle operating, safety and highway maintenance cost savings were evaluated over a range of general improvement types and operating conditions typical of the National Highway System. The results of these generalized cases were then used to prepare nomographs or regression equations and applied to over 2,000 individual improvements over the National Highway System proposed under the NHP. Approximately $10 billion in benefits were identified at a discount rate of 10% over 25 years. **The statements of benefits are indicative of the level of benefits which would be realized at the system level across the entire National Highway System. They cannot be taken as a definitive statement of benefits for individual cases.**

This evaluation for the Royal Commission on Passenger Transportation is a review of the database developed for the NHP User Benefits Analysis and has several goals related to the objectives of the Commission. The raw data prepared for the NHP User Benefits Study has been developed into a microcomputer database with the cost data added into it. The database can now be used to answer strategic questions about the NHP proposals and hence enhance the Commission's understanding of them.

1.2 Objectives

The specific objectives of this study are to:

a) Prepare a microcomputer file of NHP benefits and costs by improvement type and link.

b) Assess the distribution of benefits between passenger and freight traffic.

c) Identify priorities among improvements proposed by the NHP.

d) Identify the division between costs aimed at correcting deterioration in the existing National Highway System and costs aimed at upgrading the system to the minimum standards.

e) Assess the sensitivity of the benefits determined in task b) to plausible changes in the parameters influencing the benefits.

2.0 MICROCOMPUTER FILE OF "NATIONAL HIGHWAY POLICY" BENEFITS

This section documents the microcomputer files developed from the raw data in the NHP User Benefits Study. In addition to developing the raw data to a computer format, cost data and the split between passenger and commercial benefits have also been introduced. There is one record for each of the 2,400 improvements listed in the original NHP proposals. These are the improvements and costs identified by each province or territory as improvements falling within the National Highway Policy.

The capital costs for improvements identified under the National Highway Policy total \$11.6 billion according to a summary of proposed improvements, provided by the various provinces. The information provided in these summary sheets are dated to Mid-1989. However Phase 2 report prepared by the National Highway Policy Steering Committee, dated November 1989, identifies total improvement costs as \$12.4 billion (excluding those expenditures directly within the federal jurisdiction).

The discrepancy of \$0.8 billion in improvement costs is mainly due to the differences in cost estimates for the provinces of British Columbia, Alberta, Quebec and New Brunswick. Contacts were made with TAC (Transportation Association of Canada) officials, who were responsible for summarizing the provincial cost estimates in the earlier NHP Report, to seek a possible explanation for the discrepancy in cost estimates. The officials reviewed their files for each of the four provinces noted above but could not identify the source of the differences. However, they did advise that the provinces continued to update their estimates between mid-1989, which were the estimates provided to us, and November 1989 when they were published. This suggests the differences stem from the updates made by the provinces from the time we received the cost estimates to when they were published. However, the details of any updates that might have been made could not be confirmed.

Basically, only the project costs were changed in the Steering Committee's Phase 2 report; the benefits remained essentially as estimated in the 1989 "National Highway Policy User Benefits" report prepared by ADI Limited. It is also worth noting that the cost estimates provided by the provinces are preliminary in nature and a discrepancy of \$0.8 billion in \$12.4 billion (i.e. a 6.5% difference) is within the accuracy limits of the estimates themselves. With regards to the implication of this discrepancy, it is considered that the analysis will not be distorted at the system level, the primary focus of this analysis.

The benefits presented in the database are representative of benefits at the system level and are not intended to accurately reflect benefits at the individual case level. Each record contains the type of improvement, province, location, length, benefit and cost data. Benefits are discounted at 10% over a period of 25 years. A plausible discount rate of 5% is handled in the sensitivity analysis section. There are 9 general improvement types including:

1. Resurfacing
2. Reconstruction to a minimum RAU100 standard
3. Bypass projects
4. Twinning
5. Interchanges
6. Bridge rehabilitations
7. New bridges
8. Drainage
9. Property acquisition

For convenience, the database files are provided both in a Dbase IV format under the file name NHP.DBF and in a lotus format under the file names NHP1.WK1 (records 1 to 800), NHP2.WK1 (records 801 to 1600) and NHP3.WK1 (records 1,601 to 2,400). The estimated benefits are categorized into time saving, vehicle operating, safety and highway maintenance benefits; time saving and vehicle operating benefits are further categorized into passenger and commercial vehicle benefits.

The following descriptions present the exact data field names contained in the database and describe their contents:

PROVINCE — Each record identifies the province or territory in which a specific improvement is located. One of the following 12 province codes will appear in this field for each record: **BC, ALTA, SASK, MAN, ONT, QUE, NB, NS, PEI, NFLD, YK, NWT**

IMPRTYPE — This refers to the type of improvement proposed. There are 9 general categories corresponding to the categories used by the provinces in the NHP User Benefits Analysis. In some cases these major categories have been further subdivided (i.e. 1A, 1B etc.) to assist in assessing benefits. The IMPRTYPE field will contain one of the following improvement type codes:

1A **Resurfacing to improve ride quality (RCI<6)**
This includes pavements resurfaced to provide a minimum Ride Comfort Index (RCI) of 6. Typically this is done to intervene before pavement deterioration becomes more rapid due to cracking and higher dynamic loads.

1B **Resurfacing to strengthen the pavement**
These are pavements resurfaced to increase bearing strength during spring thaw periods and thereby prevent spring weight reductions.

2 **Reconstruction to bring the highway up to a minimum RAU100 standard**
This generally involves realignment of existing roads to remove substandard curves or grades, paving shoulders or intersection improvements.

3A **Two lane bypass of an unsignalized low speed section**
This is generally a new road alignment around a built up area which has reduced speed zones. The old alignment through the built up area continues to be used by local traffic while through traffic uses the bypass. The bypass is not necessarily warranted for congestion but rather is intended to maintain speeds over a section of highway.

3B **Two lane bypass of a signalized section (spot speed restriction)**
This is similar to 3A except that the bypassed section contains signalized intersections.

3C **Four lane bypass**
This is usually a new 4-lane alignment bypassing an existing 2-lane alignment and is normally built to relieve congestion. The old 2-lane alignment continues to be used by local traffic.

4 **Twinning**
A 2-lane alignment is expanded into 4-lanes using the same alignment. This is normally done to relieve congestion. Twinning differs from bypass projects in that the existing alignment is used instead of a new alignment. Both local and through traffic use the same alignment unless parallel service roads are included as part of the improvement.

5A **Interchange (replacing an intersection)**
This generally includes interchanges which replace existing at-grade intersections. New interchanges, such as those created to build a bypass, do not result in user benefits since they are not replacing an existing at-grade intersection.

5B **Grade separation - no access**
When limited access highways are created, bridge structures are often built over the highway allowing minor roads to cross the limited access highway without providing direct access from the minor road to the highway. Drivers on the minor road must travel to the nearest interchange if they wish to have access to the highway.

5C **Interchange (no existing intersection)**
This includes interchanges built at locations where an at-grade intersection did not previously exist. An example of this is an interchange built in connection with a bypass project. The need for the interchange is generated by the new bypass alignment and not by the need to upgrade an existing at-grade intersection. These interchanges do not generate benefits by themselves but only as part of the bypass project. Benefits for these interchanges are shown as zero since benefits are already included under the bypass category. Costs of these improvements are shown separately but could be included as part of a bypass project.

already included under the bypass category. Costs of these improvements are shown separately but could be included as part of a bypass project.

6 **Bridge rehabilitation**
This involves rehabilitation of deteriorating bridge structures in order to avoid imposing weight restrictions to heavy vehicles.

7 **New bridge structure**
No benefits are associated directly with new bridge structures unless they are replacing an existing bridge at the same location. A new bridge is considered part of a new alignment and as such its benefits are part of the bypass project.

8 **Drainage (closed)**
No benefits are associated directly with this improvement type since it is normally an integral part of a larger highway improvement project.

9 **Property acquisition**
This generally includes property acquired for right of way. No user benefits are directly associated with property acquisition.

CLASS — Classification of the improvement as either a corrective measure (C) or an upgrade measure (U).

IMPRLENGTH — Where appropriate this field gives the length of improvement in kilometres. Length is shown as zero for improvement types 5 to 9.

HIGHWAY — This refers to the name or number of the highway upon which the improvement is being made.

FROM
TOO — The FROM field and the TOO field denote the specific location of the improved highway segment. The specific highway segment is typically delineated at either end by the names of intersecting highways, streets, towns or cities. Note that TOO is used as the name of the field instead of TO which is not accepted by DBASE as a field name (TO represents a logical expression).

MAJORCITY1
MAJORCITY2 — The location of many local FROM and TOO points are not easily identifiable on a large National Highway System. In order to more easily

identify the location of an improvement, the two fields MAJORCITY1 and MAJORCITY2 have also been introduced. These are the major cities on either side of the specific section delineated by the FROM and TOO points.

AADT — This is the 1988 Average Annual Daily Traffic on the highway segment as taken from provincial highway records.

CONCOST — This is a class D estimate prepared by the provinces for the capital cost of improvement (1989 $) in thousands of dollars.

PTIMEBEN10 — This field refers to the time saving benefits (thousands of 1989 dollars) for passenger vehicles discounted over 25 years at 10%. The values of time used and auto occupancy rates used are presented in Appendix A.

CTIMEBEN10 — These are the time saving benefits (thousands of 1989 dollars) for commercial vehicles discounted over 25 years at 10%. The values of time used and vehicle occupancy rates used are presented in Appendix A.

PVEHBEN10 — This field represents the vehicle operating cost savings in thousands of 1989 $ for passenger vehicles discounted over 25 years at 10%. Operating cost items and depreciation values are presented in Appendix A.

CVEHBEN10 — This field represents the vehicle operating cost savings in thousands of 1989 $ for commercial vehicles discounted over 25 years at 10%. Operating cost items and depreciation values are presented in Appendix A.

TIMEBEN10 — These are the time saving benefits (thousands of 1989 dollars) for passenger and commercial vehicles discounted over 25 years at 10%. The values of time used and vehicle occupancy rates used are presented in Appendix A.

VEHBEN10 — This field represents the vehicle operating cost savings in thousands of

1989 $ for passenger and commercial vehicles discounted over 25 years at 10%. Operating cost items and depreciation values are presented in Appendix A.

SAFEBEN10	This field represents the accident cost savings in thousands of 1989 $ for passenger and commercial vehicles discounted over 25 years at 10%. Accident cost assumptions are presented in Appendix A.
HWYBEN10	This field represents savings in highway maintenance costs in thousands of 1989 $ for passenger and commercial vehicles discounted over 25 years at 10%. Highway maintenance cost assumptions are presented in Appendix A.
TOTALBEN10	Total of passenger and commercial user benefits discounted over 25 years at 10%.

3.0 DISTRIBUTION OF "NATIONAL HIGHWAY POLICY" USER BENEFITS BETWEEN PASSENGER AND FREIGHT TRAFFIC

The objective of this task is to assess the relative magnitudes of benefits accruing to passenger and freight traffic as a result of the NHP proposals. In the database, this has been accomplished by separately identifying time and vehicle operating cost savings for passenger and commercial traffic for each individual improvement record.

Unlike time costs and vehicle operating costs, accident costs and highway maintenance costs are not readily distinguishable between passenger and commercial vehicles. A typical accident may involve both vehicle types and may affect the occupants of either or both vehicles, thus making it difficult to allocate the resulting accident cost to the respective vehicle types. Many highway maintenance costs (eg. striping, mowing, culvert & ditch cleaning, snow removal) are "common" costs which cannot be attributed uniquely to each of the vehicle types, and could only be assigned to them somewhat arbitrarily. Though intuition suggests higher maintenance costs could be assigned to commercial vehicles (primarily for paved surface maintenance), such an allocation is difficult at best and could not be undertaken with the information available to the study team for the roads involved. Hence, safety benefits and highway maintenance benefits are not broken down by vehicle type in the database.

Exhibit 3.1 presents a summary taken from the database showing the distribution of estimated benefits (25 years, 10% discount) by benefit type for each general type of improvement. Exhibit 3.2 presents an allocation of time saving and vehicle operating benefits between passenger and commercial traffic.

Benefits are largely driven by time savings which typically represent 60% to 70% of user benefits. Any improvement which shortens travel time without increasing vehicle operating costs tends to produce large benefits.

Vehicle operating cost savings are often small or negative since highway improvements typically result in higher, less fuel efficient operating speeds. Individual exceptions to this typically occur where a new alignment is straighter or shorter than the existing alignment which results in fewer vehicle kilometres being driven. Highway maintenance benefits are negative for improvements such as bypasses and twinning which require additional highway lengths (lane-km).

Some comments may be made about benefit distribution for individual improvement types:

RCI Improvements — Resurfacing to improve ride quality mainly results in time-saving and vehicle operating savings while highway maintenance savings account for the rest. Operating costs of trucks are more sensitive to roughness than passenger cars and this is reflected as higher benefits. Time savings are usually positive due to higher speeds but accident cost savings are usually negative due to higher operating speeds. Time saving benefits

EXHIBIT 3.1
Distribution of NHP User Benefits by Benefit Type
(Millions 1989$ - 10% Discount rate)

Improvement type	Description	Time saving	Vehicle operating	Safety	Highway maintenance	Total
1A	RCI Improvements	619	858	0	31	1509
1B	Pavement strengthening	356	493	0	19	868
2	RAU 100 improvements	268	61	42	0	371
3A	Two lane bypass - unsignalized	210	-30	60	-37	202
3B	Two lane bypass - signalized	621	-64	96	-13	641
3C	Four lane bypass	782	132	203	-119	999
4	Twinning	1854	-436	355	-584	1190
5A	Interchanges	1162	57	237	-19	1438
5B	Grade separations	-3	-2	63	0	58
6	Bridge rehabilitation	901	2122	0	0	3022
	TOTAL	6770	3192	1057	-721	10298

EXHIBIT 3.2
Distribution of Time Saving and Vehicle Operating Benefits Between Passenger and Commercial Traffic (Millions 1989$ - 10% Discount rate)

Improvement type	Description	Time saving benefits			Vehicle operating benefits		
		Passenger	Commercial	Total	Passenger	Commercial	Total
1A	RCI improvements	533	86	619	361	498	859
1B	Pavement strengthening	306	49	355	207	286	493
2	RAU 100 improvements	226	42	268	-13	74	61
3A	Two lane bypass - unsignalized	168	42	210	-12	-19	-30
3B	Two lane bypass - signalized	487	134	621	-26	-38	-64
3C	Four lane bypass	691	92	783	98	34	132
4	Twinning	1631	223	1854	-296	-139	-436
5A	Interchanges	849	314	1162	43	14	57
5B	Grade separations	-2	-1	-3	-2	-1	-3
6	Bridge rehabilitation	0	901	901	0	2122	2122
	TOTAL	4887	1883	6770	361	2831	3192

also disappear as volume or grades increase since speeds then become governed by capacity and not ride quality. Highway maintenance costs are reduced since resurfacing reduces the rate at which the pavement deteriorates. Typically, a rough pavement has higher dynamic loading than a smooth pavement which results in more rapid deterioration.

Pavement strengthening

This improvement has been treated as equivalent to resurfacing for ride quality. In practical terms, the net result is the same with improved ride quality and longer pavement life.

RAU100 Improvements

Upgrading the road to a higher design standard does not normally result in substantial benefits unless it results in higher operating speeds. Again time savings start to disappear as volume or grades increase and speeds become limited by capacity instead of alignment. Truck operating savings are positive while passenger car operating costs are negative since heavy vehicles benefit from reductions in grade and curvature resulting in fewer speed changes and lower tire wear while passenger vehicles tend to speed up and use more fuel. Accident savings are positive but disappear at higher volumes where speeds are controlled by capacity and not alignment.

Two-Lane Bypass

These improvements are typically implemented in order to bypass a low speed or built up area and thereby maintain a constant operating speed over the entire highway. The net result is generally higher operating speeds and often a longer alignment. This often results in some time savings and higher vehicle operating costs. Where the new alignment bypasses a signalized section then time savings are typically much better for both car and truck when compared to a bypass of an unsignalized section.

Four-Lane Bypass

Four-lane bypasses are implemented for reasons of congestion on the existing route and as a consequence the main benefits are time savings. 69% of total benefits are time savings to cars and 9% of total benefits are time savings to trucks. 4-lane bypasses often follow a shorter alignment than the bypassed 2-lane route which results in lower vehicle operating costs even though speeds are higher. Accident savings are positive since fewer vehicle kilometres are being driven and the new alignment is generally safer.

Twinning

Twinning an existing 2-lane route does not result in a shorter alignment but does address congestion costs which are again primarily time savings for both cars and trucks. Car and truck operating costs increase since the alignment is not shorter but there is a significant increase in operating speeds and hence fuel costs.

Interchanges

Interchanges increase vehicle kilometres of travel but reduce speed change cycles which contributes to positive vehicle operating savings. Time savings are accrued by eliminating the deceleration-stop-acceleration cycle associated with signalized at-grade intersections.

Bridge Rehabilitation

The benefits of bridge rehabilitation accrue entirely to trucks by preventing load restrictions which would result in either longer trips to avoid a bridge or more trips with a reduced load. Most bridge rehabilitations would occur in any event as part of the "do minimum" scenario. User benefits generated through bridge rehabilitation proposed as part of the NHP improvements should therefore be treated with caution.

4.0 PRIORITIES AMONG "NATIONAL HIGHWAY POLICY" PROPOSALS

The objective of this task is to assess priorities amongst NHP proposals according to improvement type or according to major route. Since the database contains both costs and benefits it is possible to sum them by improvement type or by major city pair.

Exhibit 4.1 helps to assess priorities among the various improvement types on the basis of their average costs and benefits.

The most cost effective improvement types are those which reduce travel time without increasing vehicle operating costs. Bridge rehabilitations, for example, reduce both travel time and vehicle operating costs effectively by either reducing the number of trips or alternatively shortening the route travelled by trucks.

The least cost effective improvements are those which increase travel time, vehicle operating costs or highway maintenance costs. Bypasses for example often result in longer travel distance at a higher, less fuel efficient speed and increase the amount of highway maintenance costs due to the addition of a new road rather than replacing an existing one. Bypasses become more cost effective in the case of a bypass of a section with traffic signals due to large time savings.

Repaving results in pavement life cycle cost savings and time savings due to higher speeds. RAU100 improvements generally involve costly changes to alignment aimed at reducing accidents. Time savings tend to disappear over the years as the operating speed becomes limited by traffic volume instead of alignment.

Exhibit 4.2 identifies the major city pairs on the National Highway System and the length or number of proposed improvements between each city pair.

Exhibit 4.3 presents the estimated benefits and costs of these improvements between each major city pair.

Exhibit 4.4 helps to assess the priorities among proposals for the identified links on the basis of their aggregate costs and benefits.

EXHIBIT 4.1
Summary of Benefits and Costs by Improvement Type
(Millions 1989 $ - 10% Discount Rate)

Improvement type	Description	Benefit (B)	Cost (C)	B/C	B - C
1A	RCI improvements	1510	944	1.60	566
1B	Pavement strengthening	868	298	2.91	570
2	RAU 100 improvements	370	1371	0.27	-1001
3A	2 lane bypass (unsignalized)	202	337	0.60	-135
3B	2 lane bypass (signalized)	640	282	2.27	358
3C	4 lane bypass	999	1819	0.55	-820
4	Twinning	1191	3366	0.35	-2175
5A	Interchange construction	1439	1662	0.87	-223
5B	Grade separation	57	227	0.25	-170
6	Bridge rehabilitation	3022	186	16.25	2836

EXHIBIT 4.2

Length or Number of Proposed Improvements Over Major Highway Links

				IMPROVEMENT TYPE				
PROVINCE	HIGHWAY	FROM	TO	1A RCI (km)	1B Pavement str. (km)	2 RAU 100 (km)	3A 2 ln byp. (unsig.) (km)	3B 2 ln byp. (sig.) (km)
ALTA	TCH 1	Banff	Sask. Boundary	104	N/A	N/A	N/A	N/A
	Hwy 16	Jasper	Lloydminster	130	N/A	N/A	N/A	27
	Hwy 2	Edmonton	Ft. MacLeod	166	N/A	29	15	23
	Hwy 3	B.C. Border	Medicine Hat	60	N/A	48	36	34
	Hwy 43	Valleyview	Edmonton	117	N/A	N/A	N/A	8
BC	TCH 1	Vancouver	Golden	260	N/A	59	N/A	N/A
	Hwy 16	Prince Rupert	Alta. Border	829	N/A	590	22	20
	Hwy 3	Hope	Sparwood	329	N/A	19	N/A	12
	Hwy 97	Fort St. John	Kamloops	915	N/A	652	N/A	5
MAN	PTH 16	Russell	Portage La Prairie	28	N/A	N/A	23	N/A
	TCH 1	Winnipeg	Falcon Lake	29	28	N/A	N/A	N/A
	TCH 1	Kirkella	Winnipeg	222	78	N/A	N/A	N/A
NB	Route 1	U.S. Border	Sussex	33	N/A	N/A	3	N/A
	TCH 2	Fredericton	N.S. Border	N/A	N/A	N/A	N/A	N/A
	Route 7	Fredericton	St. John	N/A	N/A	N/A	N/A	N/A
NFLD	TCH 1	Port Aux Basques	Corner Brook	N/A	N/A	66	N/A	N/A
	TCH 1	Corner Brook	Gander	188	188	273	17	5
	TCH 1	Gander	St. John's	91	91	31	5	N/A
NS	TCH 104	Amherst	Sydney	N/A	N/A	N/A	N/A	13
NWT	Hwy 3	Fort Providence	Yellowknife	N/A	7	332	N/A	N/A
ONT	TCH 11	Thunder Bay	North Bay	556	N/A	N/A	N/A	N/A
	TCH 11	Fort Frances	Thunder Bay	25	N/A	N/A	N/A	N/A
	TCH 17	Thunder Bay	Sudbury	293	N/A	N/A	N/A	N/A
	TCH 17	Sudbury	Ottawa	233	N/A	N/A	N/A	N/A
	Hwy 401	Windsor	Toronto	165	N/A	N/A	N/A	N/A
	Hwy 401	Toronto	Quebec border	409	N/A	N/A	N/A	N/A
QUE	Hwy 117	Ontario border	Montreal	308	217	295	46	N/A
	Hwy 138	Quebec	Sept. Iles	73	47	62	4	N/A
	Hwy 20	Ontario border	Quebec	157	216	15	N/A	N/A
	Hwy 40	Ontario border	Quebec	286	287	100	N/A	N/A
SASK	Hwy 1-10	Moose Jaw	Regina	78	N/A	N/A	N/A	N/A
	Hwy 1-8	Regina	Manitoba border	28	N/A	N/A	N/A	N/A
	Hwy 16-26	North Battleford	Saskatoon	4	9	N/A	N/A	N/A
YK	Alaska Hwy	Beaver Creek	Watson Lake	514	514	911	N/A	N/A
	S. Klondike	Whitehorse	Skagway	74	74	182	N/A	N/A

EXHIBIT 4.2

Length or Number of Proposed Improvements Over Major Highway Links

				IMPROVEMENT TYPE				
PROVINCE	HIGHWAY	FROM	TO	3C 4 In byp. (km)	4 Twinning (km)	5A Interchanges (units)	5B Grade sepns. (units)	6 Bridge rehab. (units)
ALTA	TCH 1	Banff	Sask. Boundary	26	9	16	N/A	N/A
	Hwy 16	Jasper	Lloydminster	28	294	15	N/A	N/A
	Hwy 2	Edmonton	Ft. MacLeod	38	135	23	1	N/A
	Hwy 3	B.C. Border	Medicine Hat	N/A	19	2	1	N/A
	Hwy 43	Valleyview	Edmonton	N/A	47	1	N/A	N/A
BC	TCH 1	Vancouver	Golden	N/A	118	5	N/A	N/A
	Hwy 16	Prince Rupert	Alta. Border	N/A	10	N/A	N/A	15
	Hwy 3	Hope	Sparwood	N/A	93	N/A	N/A	N/A
	Hwy 97	Fort St. John	Kamloops	N/A	36	N/A	N/A	7
MAN	PTH 16	Russell	Portage La Prairie	N/A	N/A	N/A	N/A	14
	TCH 1	Winnipeg	Falcon Lake	N/A	19	2	N/A	12
	TCH 1	Kirkella	Winnipeg	7	45	5	1	34
NB	Route 1	U.S. Border	Sussex	55	36	12	15	N/A
	TCH 2	Fredericton	N.S. Border	111	129	38	21	N/A
	Route 7	Fredericton	St. John	9	68	3	6	N/A
NFLD	TCH 1	Port Aux Basques	Corner Brook	N/A	N/A	N/A	N/A	N/A
	TCH 1	Corner Brook	Gander	N/A	N/A	N/A	N/A	N/A
	TCH 1	Gander	St. John's	N/A	43	N/A	N/A	N/A
NS	TCH 104	Amherst	Sydney	71	148	6	9	N/A
NWT	Hwy 3	Fort Providence	Yellowknife	N/A	N/A	N/A	N/A	N/A
ONT	TCH 11	Thunder Bay	North Bay	N/A	107	N/A	N/A	25
	TCH 11	Fort Frances	Thunder Bay	N/A	81	N/A	N/A	N/A
	TCH 17	Thunder Bay	Sudbury	32	154	N/A	N/A	30
	TCH 17	Sudbury	Ottawa	12	106	N/A	N/A	13
	Hwy 401	Windsor	Toronto	N/A	N/A	N/A	N/A	34
	Hwy 401	Toronto	Quebec border	N/A	N/A	N/A	N/A	37
QUE	Hwy 117	Ontario border	Montreal	10	N/A	N/A	N/A	1
	Hwy 138	Quebec	Sept. Iles	N/A	9	N/A	N/A	N/A
	Hwy 20	Ontario border	Quebec	3	13	6	N/A	2
	Hwy 40	Ontario border	Quebec	N/A	N/A	3	N/A	N/A
SASK	Hwy 1-10	Moose Jaw	Regina	N/A	N/A	1	N/A	1
	Hwy 1-8	Regina	Manitoba border	N/A	N/A	5	N/A	N/A
	Hwy 16-26	North Battleford	Saskatoon	N/A	N/A	2	N/A	N/A
YK	Alaska Hwy	Beaver Creek	Watson Lake	N/A	N/A	N/A	N/A	N/A
	S. Klondike	Whitehorse	Skagway	N/A	N/A	N/A	N/A	N/A

EXHIBIT 4.3

Summary of Benefits and Costs for Major Highway Links (000's 1989$ - 10% Discount Rate)

				IMPROVEMENT TYPE														
				1A RCI improvements			1B Pavement strengthening			2 RAU 100 improvements			3A 2 ln byp. (unsignalized)			3B 2 ln byp. (signalized)		
PROVINCE	HIGHWAY	FROM	TO	B	C	B/C	B	C	B/C	B	C	B/C	B	C	B/C	B	C	B/C
ALTA	TCH 1	Banff	Sask. Boundary	17341	5279	3.28	0	0	N/A	0	0	N/A	0	0	N/A	0	0	N/A
	Hwy 16	Jasper	Lloydminster	21579	6610	3.26	0	0	N/A	0	0	N/A	0	0	N/A	65589	17073	3.84
	Hwy 2	Edmonton	Ft. MacLeod	31376	8445	3.72	0	0	N/A	5365	250	21.46	1510	15200	0.10	56079	85700	0.65
	Hwy 3	B.C. Border	Medicine Hat	6542	3045	2.15	0	0	N/A	7591	1791	4.24	3502	18636	0.19	83631	17101	4.89
	Hwy 43	Valleyview	Edmonton	10839	5942	1.82	0	0	N/A	0	0	N/A	0	0	N/A	19506	7000	2.79
BC	TCH 1	Vancouver	Golden	44562	15110	2.95	0	0	N/A	4772	81000	0.06	0	0	N/A	0	0	N/A
	Hwy 16	Prince Rupert	Alta. Border	62315	69373	0.90	0	0	N/A	43781	116105	0.38	4820	20525	0.23	108401	18750	5.78
	Hwy 3	Hope	Sparwood	33142	18050	1.84	0	0	N/A	1282	20050	0.06	0	0	N/A	62171	10000	6.22
	Hwy 97	Fort St. John	Kamloops	85866	85784	1.00	0	0	N/A	59485	170830	0.35	0	0	N/A	23912	35000	0.68
MAN	PTH 16	Russell	Portage La Prairie	1376	2364	0.58	0	0	N/A	0	0	N/A	44899	9330	4.81	0	0	N/A
	TCH 1	Winnipeg	Falcon Lake	2032	2482	0.82	3200	2355	1.36	0	0	N/A	0	0	N/A	0	0	N/A
	TCH 1	Kirkella	Winnipeg	19979	18864	1.06	11765	6614	1.78	0	0	N/A	0	0	N/A	0	0	N/A
NB	Route 1	U.S. Border	Sussex	5922	4613	1.28	0	0	N/A	0	0	N/A	4145	3200	1.30	0	0	N/A
	TCH 2	Fredericton	N.S. Border	0	0	N/A	0	0	N/A	0	0	N/A	0	0	N/A	0	0	N/A
	Route 7	Fredericton	St. John	0	0	N/A	0	0	N/A	0	0	N/A	0	0	N/A	0	0	N/A
NFLD	TCH 1	Port Aux Basques	Corner Brook	0	0	N/A	0	0	N/A	5720	16475	0.35	0	0	N/A	0	0	N/A
	TCH 1	Corner Brook	Gander	22569	11756	1.92	10354	11756	0.88	30685	68200	0.45	22658	6268	3.61	2372	4180	0.57
	TCH 1	Gander	St. John's	12601	5659	2.23	5782	5659	1.02	4531	7725	0.59	3026	2160	1.40	0	0	N/A
NS	TCH 104	Amherst	Sydney	0	0	N/A	0	0	N/A	0	0	N/A	0	0	N/A	8629	24600	0.35
NWT	Hwy 3	Fort Providence	Yellowknife	0	0	N/A	92	1000	0.09	1010	115310	0.01	0	0	N/A	0	0	N/A
ONT	TCH 11	Thunder Bay	North Bay	15218	57553	0.26	0	0	N/A	0	0	N/A	0	0	N/A	0	0	N/A
	TCH 11	Fort Frances	Thunder Bay	1786	1815	0.98	0	0	N/A	0	0	N/A	0	0	N/A	0	0	N/A
	TCH 17	Thunder Bay	Sudbury	10735	26661	0.40	0	0	N/A	0	0	N/A	0	0	N/A	0	0	N/A
	TCH 17	Sudbury	Ottawa	12631	25744	0.49	0	0	N/A	0	0	N/A	0	0	N/A	0	0	N/A
	Hwy 401	Windsor	Toronto	60426	21214	2.85	0	0	N/A	0	0	N/A	0	0	N/A	0	0	N/A
	Hwy 401	Toronto	Quebec border	97839	48000	2.04	0	0	N/A	0	0	N/A	0	0	N/A	0	0	N/A
QUE	Hwy 117	Ontario border	Montreal	44574	43120	1.03	14517	30380	0.48	52384	44000	1.19	29657	44000	0.67	0	0	N/A
	Hwy 138	Quebec	Sept. Iles	36719	10220	3.59	100221	6580	15.23	8158	52650	0.15	2531	5000	0.51	0	0	N/A
	Hwy 20	Ontario border	Quebec	158226	21980	7.20	227951	30240	7.54	3267	10290	0.32	0	0	N/A	0	0	N/A
	Hwy 40	Ontario border	Quebec	217825	40040	5.44	221446	40180	5.51	26785	1788	14.98	0	0	N/A	0	0	N/A
SASK	Hwy 1-10	Moose Jaw	Regina	20558	6264	3.28	0	0	N/A	0	0	N/A	0	0	N/A	0	0	N/A
	Hwy 1-8	Regina	Manitoba border	14552	2208	6.59	0	0	N/A	0	0	N/A	0	0	N/A	0	0	N/A
	Hwy 16-26	North Battleford	Saskatoon	509	272	1.87	1339	680	1.97	0	0	N/A	0	0	N/A	0	0	N/A
YK	Alaska Hwy	Beaver Creek	Watson Lake	14346	23040	0.62	491	23040	0.02	20939	236834	0.09	0	0	N/A	0	0	N/A
	S. Klondike	Whitehorse	Skagway	2332	3330	0.70	80	3330	0.02	4639	47320	0.10	0	0	N/A	0	0	N/A

EXHIBIT 4.3

Summary of Benefits and Costs for Major Highway Links (000's 1989$)

				IMPROVEMENT TYPE														
				3C 4 ln bypass			4 Twinning			5A Interchanges			5B Grade separation			6 Bridge rehabilitation		
PROVINCE	HIGHWAY	FROM	TO	B	C	B/C	B	C	B/C	B	C	B/C	B	C	B/C	B	C	B/C
ALTA	TCH 1	Banff	Sask. Boundary	16396	114700	0.14	5341	23300	0.23	175226	215996	0.81	0	0	N/A	0	0	N/A
	Hwy 16	Jasper	Lloydminster	11253	33496	0.34	12270	126479	0.10	90342	162500	0.56	0	0	N/A	0	0	N/A
	Hwy 2	Edmonton	Ft. MacLeod	11861	26250	0.45	169180	65015	2.60	87323	192148	0.45	640	28000	0.02	0	0	N/A
	Hwy 3	B.C. Border	Medicine Hat	0	0	N/A	8987	8883	1.01	7520	30000	0.25	640	46100	0.01	0	0	N/A
	Hwy 43	Valleyview	Edmonton	0	0	N/A	3169	27425	0.12	917	4000	0.23	0	0	N/A	0	0	N/A
BC	TCH 1	Vancouver	Golden	0	0	N/A	141105	253750	0.56	244504	148000	1.65	0	0	N/A	0	0	N/A
	Hwy 16	Prince Rupert	Alta. Border	0	0	N/A	5244	6100	0.86	0	0	N/A	0	0	N/A	10148	567	17.90
	Hwy 3	Hope	Sparwood	0	0	N/A	24178	183500	0.13	0	0	N/A	0	0	N/A	0	0	N/A
	Hwy 97	Fort St. John	Kamloops	0	0	N/A	897	39050	0.02	0	0	N/A	0	0	N/A	10565	153	69.05
MAN	PTH 16	Russell	Portage La Prairie	0	0	N/A	0	0	N/A	0	0	N/A	0	0	N/A	13597	9780	1.39
	TCH 1	Winnipeg	Falcon Lake	0	0	N/A	1264	13429	0.09	2462	6900	0.36	0	0	N/A	24632	9600	2.57
	TCH 1	Kirkella	Winnipeg	16593	10000	1.66	3378	16399	0.21	16443	63500	0.26	640	4000	0.16	82773	35495	2.33
NB	Route 1	U.S. Border	Sussex	74900	110000	0.68	11457	36300	0.32	31175	41000	0.76	9604	24250	0.40	0	0	N/A
	TCH 2	Fredericton	N.S. Border	129810	220600	0.59	155802	129480	1.20	103074	127500	0.81	13446	33400	0.40	0	0	N/A
	Route 7	Fredericton	St. John	11558	31850	0.36	7415	67434	0.11	3492	10500	0.33	3842	5550	0.69	0	0	N/A
NFLD	TCH 1	Port Aux Basques	Corner Brook	0	0	N/A	0	0	N/A	0	0	N/A	0	0	N/A	0	0	N/A
	TCH 1	Corner Brook	Gander	0	0	N/A	0	0	N/A	0	0	N/A	0	0	N/A	0	0	N/A
	TCH 1	Gander	St. John's	0	0	N/A	18754	30310	0.62	0	0	N/A	0	0	N/A	0	0	N/A
NS	TCH 104	Amherst	Sydney	113353	149520	0.76	88705	161900	0.55	13742	19300	0.71	5763	28200	0.20	0	0	N/A
NWT	Hwy 3	Fort Providence	Yellowknife	0	0	N/A	0	0	N/A	0	0	N/A	0	0	N/A	0	0	N/A
ONT	TCH 11	Thunder Bay	North Bay	0	0	N/A	27960	152790	0.18	0	0	N/A	0	0	N/A	101106	7050	14.34
	TCH 11	Fort Frances	Thunder Bay	0	0	N/A	14681	154000	0.10	0	0	N/A	0	0	N/A	0	0	N/A
	TCH 17	Thunder Bay	Sudbury	59396	62150	0.96	27945	494780	0.06	0	0	N/A	0	0	N/A	140596	7860	17.89
	TCH 17	Sudbury	Ottawa	69058	18260	3.78	82986	94325	0.88	0	0	N/A	0	0	N/A	109510	3406	32.15
	Hwy 401	Windsor	Toronto	0	0	N/A	0	0	N/A	0	0	N/A	0	0	N/A	223096	10812	20.63
	Hwy 401	Toronto	Quebec border	0	0	N/A	0	0	N/A	0	0	N/A	0	0	N/A	492553	11766	41.86
QUE	Hwy 117	Ontario border	Montreal	7012	18200	0.39	0	0	N/A	0	0	N/A	0	0	N/A	3312	400	8.28
	Hwy 138	Quebec	Sept. Iles	0	0	N/A	388	7800	0.05	0	0	N/A	0	0	N/A	0	0	N/A
	Hwy 20	Ontario border	Quebec	1737	16800	0.10	26876	19400	1.39	129966	34010	3.82	0	0	N/A	76441	3000	25.48
	Hwy 40	Ontario border	Quebec	0	0	N/A	0	0	N/A	82581	16600	4.97	0	0	N/A	0	0	N/A
SASK	Hwy 1-10	Moose Jaw	Regina	0	0	N/A	0	0	N/A	4834	8000	0.60	0	0	N/A	3238	600	5.40
	Hwy 1-8	Regina	Manitoba border	0	0	N/A	0	0	N/A	57483	40000	1.44	0	0	N/A	0	0	N/A
	Hwy 16-26	North Battleford	Saskatoon	0	0	N/A	0	0	N/A	6466	16000	0.40	0	0	N/A	0	0	N/A
YK	Alaska Hwy	Beaver Creek	Watson Lake	0	0	N/A	0	0	N/A	0	0	N/A	0	0	N/A	0	0	N/A
	S. Klondike	Whitehorse	Skagway	0	0	N/A	0	0	N/A	0	0	N/A	0	0	N/A	0	0	N/A

EXHIBIT 4.4
Summary of Aggregate Benefits and Costs for Major Highway Links (000's 1989 $ - 10% Discount Rate)

PROVINCE	HIGHWAY	FROM	TO	Benefit (B)	Cost (C)	B/C	B - C
ALTA	TCH 1	Banff	Sask. Boundary	214306	359275	0.60	-144969
	Hwy 16	Jasper	Lloydminster	201032	346158	0.58	-145126
	Hwy 2	Edmonton	Ft. MacLeod	363337	421009	0.86	-57672
	Hwy 3	B.C. Border	Medicine Hat	118413	125556	0.94	-7143
	Hwy 43	Valleyview	Edmonton	34431	44367	0.78	-9936
BC	TCH 1	Vancouver	Golden	434944	497860	0.87	-62916
	Hwy 16	Prince Rupert	Alta. Border	234709	231420	1.01	3289
	Hwy 3	Hope	Sparwood	120773	231600	0.52	-110827
	Hwy 97	Fort St. John	Kamloops	180725	330817	0.55	-150092
MAN	PTH 16	Russell	Portage La Prairie	59873	21474	2.79	38399
	TCH 1	Winnipeg	Falcon Lake	33591	34766	0.97	-1175
	TCH 1	Kirkella	Winnipeg	151570	154872	0.98	-3302
NB	Route 1	U.S. Border	Sussex	137203	219363	0.63	-82160
	TCH 2	Fredericton	N.S. Border	402133	510980	0.79	-108847
	Route 7	Fredericton	St. John	26307	115334	0.23	-89027
NFLD	TCH 1	Port Aux Basques	Corner Brook	5720	16475	0.35	-10755
	TCH 1	Corner Brook	Gander	88638	102160	0.87	-13522
	TCH 1	Gander	St. John's	44695	51513	0.87	-6818
NS	TCH 104	Amherst	Sydney	230192	383520	0.60	-153328
NWT	Hwy 3	Fort Providence	Yellowknife	1102	116310	0.01	-115208
ONT	TCH 11	Thunder Bay	North Bay	144283	217393	0.66	-73110
	TCH 11	Fort Frances	Thunder Bay	16466	155815	0.11	-139349
	TCH 17	Thunder Bay	Sudbury	238673	591451	0.40	-352778
	TCH 17	Sudbury	Ottawa	274185	141735	1.93	132450
	Hwy 401	Windsor	Toronto	283521	32026	8.85	251495
	Hwy 401	Toronto	Quebec border	590392	59766	9.88	530626
QUE	Hwy 117	Ontario border	Montreal	151456	180100	0.84	-28644
	Hwy 138	Quebec	Sept. Iles	148017	82250	1.80	65767
	Hwy 20	Ontario border	Quebec	624466	135720	4.60	488746
	Hwy 40	Ontario border	Quebec	548638	98608	5.56	450030
SASK	Hwy 1-10	Moose Jaw	Regina	28630	14864	1.93	13766
	Hwy 1-8	Regina	Manitoba border	72034	42208	1.71	29826
	Hwy 16-26	North Battleford	Saskatoon	8314	16952	0.49	-8638
YK	Alaska Hwy	Beaver Creek	Watson Lake	35776	282914	0.13	-247138
	S. Klondike	Whitehorse	Skagway	7051	53980	0.13	-46929

5.0 CORRECTING COSTS VS. UPGRADING COSTS

The objective of this task is to enhance the understanding of costs associated with the NHP proposals by categorizing costs as those required to correct deterioration in designed service quality and those which would upgrade performance to the minimum criteria specified for the national network. Costs of the NHP proposals are estimated to be 77% corrective. Exhibit 5.1 presents a distribution of costs and benefits by these two categories.

"Corrective measures" are defined here as improvements undertaken to restore either the level of service or the physical characteristics for which the road was originally designed. A number of basic principles were used to allocate improvement costs either to upgrading or to corrective categories:

1A Resurfacing to improve ride quality (RCI<6)
This improvement is considered as corrective since pavements normally become candidates for resurfacing as a part of normal pavement maintenance practice when RCI values drop below 6. Intervening at this stage is a corrective measure aimed at preventing further accelerated deterioration of the pavement and higher life cycle costs.

1B Resurfacing to strengthen the pavement
This may generally be considered an upgrade of the system to meet NHP objectives for design loads based on national standards for vehicle weights and dimensions and all weather operation with no seasonal weight restrictions.

2 Reconstruction to bring the highway up to a minimum RAU100 standard
This may be considered as upgrading to meet NHP geometric design guidelines for a minimum design speed of 100 km/hr which may be greater than the original design speed.

3A Two lane bypass of an unsignalized low speed section
This is an upgrade not necessarily required to alleviate a volume related decline in level of service but implemented in order to provide a continuous minimum operating speed over a section of highway. This falls under the NHP objective of having a limited access on 2-lane roads.

3B Two lane bypass of a signalized section (spot speed restriction)
This improvement type may be considered as an upgrade for the same reasons as improvement type 3A.

3C Four lane bypass
Four lane bypasses are implemented to alleviate congestion. In this sense they serve as a corrective measure implemented to restore the original level of service for which the initial roadway was designed.

EXHIBIT 5.1
Benefits and Costs - Corrective vs Upgrading
(Millions 1989 $ - 10% Discount rate)

Improvement type	Description	Benefit		Cost	
		Corrective (C)	Upgrading (U)	Corrective (C)	Upgrading (U)
1A	RCI improvements	1510	-	944	-
1B	Pavement strengthening	-	868	-	298
2	RAU 100 improvements	-	370	-	1371
3A	2 lane bypass (unsignalized)	-	202	-	337
3B	2 lane bypass (signalized)	-	640	-	282
3C	4 lane bypass	999	-	1819	-
4	Twinning	1191	-	3366	-
5A	Interchange construction	1439	-	1662	-
5B	Grade Separation	57	-	227	-
5C	New interchanges	-	-	113	-
6	Bridge rehabilitation	3022	-	186	-
7	New structure	-	-	514	353
8	Drainage	-	-	-	1
9	Property acquisition	-	-	48	29
	TOTAL	8217	2080	8879	2671
		80%	20%	77%	23%

4 **Twinning**
Twinning an existing alignment is also aimed at alleviating congestion and can be considered as a corrective measure designed to restore the original level of service for which the roadway was designed.

5A **Interchange construction**
5B **Grade separation - no access**
Interchanges and grade separations are both considered as corrective measures designed to restore the level of service and level of safety for which the original intersection was designed. The need for grade separations and interchanges is associated with twinning and 4-lane bypasses which are corrective measures.

5C **Interchange construction (no existing intersection)**
These are interchanges built at locations where no previous at-grade intersection existed. The interchange is normally associated with a 4-lane bypass constructed to restore level of service and is therefore considered a corrective measure.

6 **Bridge rehabilitation**
This is a corrective measure aimed at restoring an existing bridge to its original level of service.

7 **New bridge structure**
New structures are treated on a case by case basis depending on the kind of works the new bridge is associated with. If the new bridge is part of a 4-lane or twinning project designed to relieve congestion or to meet safety warrants as traffic grows then it may be considered as corrective. If the new bridge is proposed as a replacement for a bridge of a lower design load standard then it is an upgrade in order to meet design loads for national standards on vehicle weights and dimensions.

8 **Drainage (closed)**
9 **Property acquisition**

These 2 categories are treated on a case by case basis and classified either as upgrade or corrective depending on what type of improvement they are in support of.

6.0 SENSITIVITY ANALYSIS

The objective of this task is to assess the sensitivity of the estimated benefits to plausible changes in the variables determining these benefits. This task required several HUBAM (Highway User Benefit Assessment Model) runs along with a review of other computer outputs generated to estimate the benefits for interchanges/grade separations.

The benefits shown in the database are based on parameters used in preparing an earlier report titled "National Highway Policy User Benefits". These parameters, hereafter referred to as the baseline case, are enclosed in Appendix A.

The variables considered for sensitivity analysis are shown below along with their baseline values.

- Discount Rate (10% over a planning period of 25 years)
- Fuel price ($0.268/L for Auto & Straight truck, $0.299/L for Combination vehicle) net of taxes
- Value of Time for Auto ($13.64/hr for work and $3.41/hr for non-work trips)
- Cost per fatal accident ($368,000/fatal accident)
- Traffic growth rate (2%)

The sensitivity analysis was performed to estimate the proportional change in benefits due to plausible changes. The impact of these changes on total NHP User benefits is summarized below:

Plausible change	NHP User Benefits ($ Millions 1989)
Baseline	**10,298**
Change discount rate from 10% to 5%	17,028
Increase fuel price by 50%	10,767
Increase Auto time value by 50%	12,628
Decrease Auto time value by 50%	7,968
Increase fatal accident cost from $368,000 to $1.4M	12,139
Increase fatal accident cost from $368,000 to $2.5M	14,114
Traffic growth rate increases from 2% to 3%	11,618

In order to make the conclusions from the sensitivity analysis absolute in nature, the results have been tabulated in Exhibits 6.1 to 6.9 in the form of multiplying factors used to convert the baseline benefit to actual benefit for the sensitivity case being considered. The Exhibits identify the change in benefits by individual benefit type (i.e. vehicle operating, time, accident and highway maintenance savings). They can be used to assess the sensitivity of a benefit to one or more changes simultaneously. Interpretation of the sensitivity analysis exhibits is best illustrated by means of an example taken from one of the NHP proposals.

Problem

A twinning improvement project results in the following User benefits using the baseline assumptions:

	($ in 000's)
Vehicle operating	: -3,353
Time	: 14,264
Accident	: 2,740
Hwy maintenance	: -4,489
TOTAL	: 9,162

Determine the total savings for the following two sensitivity cases.
Case 1 - Discount rate changes to 5%
Case 2 - Discount rate changes to 5% along with an auto time value increase by 50%

Solution

Case 1 — From Exhibit 6.6, a change in discount rate from 10% to 5% varies the benefits by the following factors:

Multiplying factors	
Vehicle operating	: 1.65
Time	: 1.74
Accident	: 1.67
Hwy maintenance	: 2.11

Sensitivity case savings ($ in 000's)	
Vehicle operating	: 1.65(-3,353) = -5,533
Time	: 1.74(14,264) = 24,820
Accident	: 1.67(2,740) = 4,576
Hwy maintenance	: 2.11(-4,489) = -9,472
TOTAL	: 14,391 ♦

EXHIBIT 6.1 - SENSITIVITY ANALYSIS FOR THE IMPROVEMENT TYPE SHOWN

1A & 1B - RCI/Pavement strengthening

Sensitivity Case	Multiplying factors to account for plausible changes in the input parameters			
	Veh Oper savings	Time savings	Accident savings	Hwy maint. savings
Baseline	1.00	1.00		1.00
Discount rate = 5%	1.58	1.57		1.00
Fuel price incr. by 50%	1.01	1.00		1.00
Auto time value incr.by 50%	1.00	1.40		1.00
Auto time value decr.by 50%	1.00	0.60		1.00
Fatal acc. cost incr. to $1.4M	1.00	1.00		1.00
Fatal acc. cost incr. to $2.5M	1.00	1.00		1.00
Traffic growth rate incr. to 3%	1.09	1.11		1.00

Note:
The shaded portion denotes a benefit type not applicable to the improvement type under consideration

EXHIBIT 6.2 - SENSITIVITY ANALYSIS FOR THE IMPROVEMENT TYPE SHOWN

2 - RAU100 improvements

Sensitivity Case	Multiplying factors to account for plausible changes in the input parameters			
	Veh Oper savings	Time savings	Accident savings	Hwy maint. savings
Baseline	1.00	1.00	1.00	
Discount rate = 5%	1.64	1.66	1.67	
Fuel price incr. by 50%	1.12	1.00	1.00	
Auto time value incr.by 50%	1.00	1.40	1.00	
Auto time value decr.by 50%	1.00	0.60	1.00	
Fatal acc. cost incr. to $1.4M	1.00	1.00	2.84	
Fatal acc. cost incr. to $2.5M	1.00	1.00	4.80	
Traffic growth rate incr. to 3%	1.14	1.11	1.11	

Note:
The shaded portion denotes a benefit type not applicable to the improvement type under consideration

EXHIBIT 6.3 - SENSITIVITY ANALYSIS FOR THE IMPROVEMENT TYPE SHOWN

3A - Two lane bypass (unsignalized)

Sensitivity Case	Multiplying factors to account for plausible changes in the input parameters			
	Veh Oper savings	Time savings	Accident savings	Hwy maint. savings
Baseline	-1.00	1.00	1.00	-1.00
Discount rate = 5%	1.64	1.66	1.67	1.82
Fuel price incr. by 50%	1.07	1.00	1.00	1.00
Auto time value incr.by 50%	1.00	1.40	1.00	1.00
Auto time value decr.by 50%	1.00	0.60	1.00	1.00
Fatal acc. cost incr. to $1.4M	1.00	1.00	2.84	1.00
Fatal acc. cost incr. to $2.5M	1.00	1.00	4.80	1.00
Traffic growth rate incr. to 3%	1.06	1.08	1.08	1.00

Note:
Vehicle operating savings and Highway maintenance savings are typically negative for two-lane bypass improvements as indicated by negative baseline factors

EXHIBIT 6.4 - SENSITIVITY ANALYSIS FOR THE IMPROVEMENT TYPE SHOWN

3B - Two lane bypass (signalized)

Sensitivity Case	Multiplying factors to account for plausible changes in the input parameters			
	Veh Oper savings	Time savings	Accident savings	Hwy maint. savings
Baseline	-1.00	1.00	1.00	-1.00
Discount rate = 5%	1.58	1.63	1.61	1.80
Fuel price incr. by 50%	1.24	1.00	1.00	1.00
Auto time value incr.by 50%	1.00	1.40	1.00	1.00
Auto time value decr.by 50%	1.00	0.60	1.00	1.00
Fatal acc. cost incr. to $1.4M	1.00	1.00	2.84	1.00
Fatal acc. cost incr. to $2.5M	1.00	1.00	4.80	1.00
Traffic growth rate incr. to 3%	1.06	1.08	1.08	1.00

Note:
Vehicle operating savings and Highway maintenance savings are typically negative for two-lane bypass improvements as indicated by negative baseline factors

EXHIBIT 6.5 - SENSITIVITY ANALYSIS FOR THE IMPROVEMENT TYPE SHOWN

3C - Four lane bypass

Sensitivity Case	Multiplying factors to account for plausible changes in the input parameters			
	Veh Oper savings	Time savings	Accident savings	Hwy maint. savings
Baseline	1.00	1.00	1.00	-1.00
Discount rate = 5%	1.64	1.72	1.67	1.90
Fuel price incr. by 50%	0.98	1.00	1.00	1.00
Auto time value incr.by 50%	1.00	1.40	1.00	1.00
Auto time value decr.by 50%	1.00	0.60	1.00	1.00
Fatal acc. cost incr. to $1.4M	1.00	1.00	2.84	1.00
Fatal acc. cost incr. to $2.5M	1.00	1.00	4.80	1.00
Traffic growth rate incr. to 3%	1.21	1.23	1.08	1.00

Notes:
Highway maintenance savings are typically negative for four-lane bypass improvements as indicated by a negative baseline factor

EXHIBIT 6.6 - SENSITIVITY ANALYSIS FOR THE IMPROVEMENT TYPE SHOWN

4 - Twinning

Sensitivity Case	Multiplying factors to account for plausible changes in the input parameters			
	Veh Oper savings	Time savings	Accident savings	Hwy maint. savings
Baseline	-1.00	1.00	1.00	-1.00
Discount rate = 5%	1.65	1.74	1.67	2.11
Fuel price incr. by 50%	1.40	1.00	1.00	1.00
Auto time value incr.by 50%	1.00	1.40	1.00	1.00
Auto time value decr.by 50%	1.00	0.60	1.00	1.00
Fatal acc. cost incr. to $1.4M	1.00	1.00	2.84	1.00
Fatal acc. cost incr. to $2.5M	1.00	1.00	4.80	1.00
Traffic growth rate incr. to 3%	1.01	1.29	1.11	1.00

Note:
Vehicle operating savings and Highway maintenance savings are typically negative for twinning improvements as indicated by negative baseline factors

EXHIBIT 6.7 - SENSITIVITY ANALYSIS FOR THE IMPROVEMENT TYPE SHOWN

5A - Interchanges

Sensitivity Case	Multiplying factors to account for plausible changes in the input parameters			
	Veh Oper savings	Time savings	Accident savings	Hwy maint. savings
Baseline	1.00	1.00	1.00	-1.00
Discount rate = 5%	1.67	1.63	2.74	1.74
Fuel price incr. by 50%	4.17	1.00	1.00	1.00
Auto time value incr.by 50%	1.00	1.40	1.00	1.00
Auto time value decr.by 50%	1.00	0.60	1.00	1.00
Fatal acc. cost incr. to $1.4M	1.00	1.00	2.40	1.00
Fatal acc. cost incr. to $2.5M	1.00	1.00	3.90	1.00
Traffic growth rate incr. to 3%	1.05	1.05	1.05	1.00

Note:
Highway maintenance savings are typically negative for interchange improvements as indicated by negative baseline factors

EXHIBIT 6.8 - SENSITIVITY ANALYSIS FOR THE IMPROVEMENT TYPE SHOWN

5B - Grade separations

Sensitivity Case	Multiplying factors to account for plausible changes in the input parameters			
	Veh Oper savings	Time savings	Accident savings	Hwy maint. savings
Baseline	-1.00	-1.00	1.00	
Discount rate = 5%	1.62	1.66	2.21	
Fuel price incr. by 50%	4.17	1.00	1.00	
Auto time value incr.by 50%	1.00	1.40	1.00	
Auto time value decr.by 50%	1.00	0.60	1.00	
Fatal acc. cost incr. to $1.4M	1.00	1.00	2.84	
Fatal acc. cost incr. to $2.5M	1.00	1.00	4.80	
Traffic growth rate incr. to 3%	1.05	1.05	1.05	

Notes:
(1) The shaded portion denotes a benefit type not applicable to the improvement type under consideration
(2) Vehicle operating savings and Time savings are typically negative for grade separation improvements as indicated by negative baseline factors

EXHIBIT 6.9 - SENSITIVITY ANALYSIS FOR THE IMPROVEMENT TYPE SHOWN

6 - Bridge rehabilitation

Sensitivity Case	Multiplying factors to account for plausible changes in the input parameters			
	Veh Oper savings	Time savings	Accident savings	Hwy maint. savings
Baseline	1.00	1.00		
Discount rate = 5%	1.67	1.67		
Fuel price incr. by 50%	1.22	1.00		
Auto time value incr.by 50%	1.00	1.00		
Auto time value decr.by 50%	1.00	1.00		
Fatal acc. cost incr. to $1.4M	1.00	1.00		
Fatal acc. cost incr. to $2.5M	1.00	1.00		
Traffic growth rate incr. to 3%	1.03	1.03		

Notes:
The shaded portion denotes a benefit type not applicable to the improvement type under consideration

Case 2 — From Exhibit 6.6, an increase in auto time value by 50% increases time savings by a factor of 1.40. Vehicle operating, accident and highway maintenance savings remain unchanged.

Sensitivity case savings ($ in 000's)

Vehicle operating	: -5,533
Time	: 1.4(24,820) = 34,748
Accident	: 4,576
Hwy maintenance	: -9,472
TOTAL	: 24,319 ♦

A brief summary of results from the sensitivity tests follow.

Baseline

The multiplying factors for baseline benefits equals ±1.00 for all applicable saving types.

Discount Rate equals 5%

A change of discount rate from 10% to 5% typically increases the total absolute baseline benefit by 50% to 70%. Lowering the discount rate assigns greater importance to the benefits which occur late in the planning period. This generally favours capacity improvements (eg. twinning) with large time savings since normal traffic growth would lead to increasing congestion later in the planning period. With a lower discount rate these benefits are not as heavily discounted.

For RCI and Pavement strengthening improvements (improvements with positive highway maintenance savings), highway maintenance savings are the same as for the baseline case. This is because highway maintenance savings for these improvements are comprised of both positive maintenance savings and negative periodic resurfacing savings which when discounted together cancels the overall discounting effect.

Fuel Price increases by 50%

An increase in fuel price increases the proportion of user benefits made up by vehicle operating savings. This means higher benefits for projects which shorten alignment (some bypasses) or improve pavement surface (resurfacing), and lower benefits for projects which increase speed or lengthen alignment (most bypasses or capacity improvements).

Vehicle operating savings consist of fuel, oil, tires, repairs and depreciation savings. An increase in fuel price hence need not necessarily increase the absolute savings. For example, fuel saving is negative for a four-lane bypass though the overall vehicle operating saving is positive for a typical NHP improvement wherein the bypass length is shorter than the existing route. An increase in fuel price will hence decrease the overall vehicle operating saving for a four-lane bypass. Vehicle operating savings offered by an interchange/grade separation are positive due to positive fuel savings even though vehicle maintenance savings are negative. An increase in fuel price increases fuel savings without affecting vehicle maintenance savings; this is reflected by a relatively high multiplying factor for interchanges. RCI improvements are only marginally affected as indicated by a multiplying factor close to one.

Value of Auto time increases or decreases

The effect of any change in value of time for automobiles is to vary the baseline time savings by an appropriate factor. This factor depends on the magnitude of change in time value and is not a function of the improvement type. Given that automobiles represent 87% of the total traffic for the links under NHP improvements, this factor is determinable by a simple calculation. Such a calculation is presented in Appendix C. Results show that an increase in Auto time value by 50% increases time savings by 40% and a decrease in Auto time value by 50% decreases time savings by 40%. The sensitivity of time savings to similar changes in time value of commercial vehicles is equally simple to calculate as well.

Increase in Unit Cost of Fatal Accident

Fatal accidents typically account for less than 3% of all accidents but 80% of accident costs. For this reason the cost assigned to a fatal accident strongly influences overall accident savings.

The effect of any change in the cost per fatal accident on the overall accident saving is to vary the baseline accident saving by a factor depending on the magnitude of change in cost and accident distribution. Given these two parameters, the appropriate factor can be determined by a simple calculation as shown in Appendix C. An accident distribution of 3:34:63 (fatal:injury:property damage) was used for improvement types other than interchanges; in case of interchanges, a distribution of 1.4:25.8:72.8 was used which explains the difference in the multiplying factor for interchanges as compared to other improvement types.

Increase in Traffic Growth Rate

The impact of traffic growth rate on total savings becomes less significant when high discount rates are used because potential large future user benefits are heavily discounted. An increase in traffic growth rate typically results in an absolute increase in vehicle operating, time and accident savings, and hence increases total savings. Highway maintenance savings are not significantly affected by the analyzed increase in traffic growth rate.

APPENDIX A

NATIONAL HIGHWAY POLICY INPUT PARAMETERS

FIGURE A.1
CONTROL PARAMETERS FOR HUBAM

Item	Value
Type of Evaluation	Prospective
Program Start Year	1989
Base Year	1989 Cost factors from earlier years will be adjusted to 1989 using CPI.
Planning Period	25 years
Discount Rate	5% and 10%
Inflation Rate	0% (constant 1989 dollars)
Average Temperature	Summer +15 deg C. Winter -5 deg C. Temperature determines correction for fuel consumption.

FIGURE A.2
TRAFFIC

	Growth Rate (1)		
VEHICLE	Before 1996	After 1996	SPLIT
Auto	2.8%	2%	87%
S-U Truck	2.5%	2%	1%
M-U Truck	2.5%	2%	9%
Bus	2.1%	2%	0%
RV	2.8%	2%	3%

(1) Source: "Freight and Passenger Forecasts 1988" Transport Canada, Macroeconomic and Regional Analysis Branch. Forecasts are to year 1996.

Traffic growth after 1996 has been projected at 2% per annum which is consistent with historical growth between 1976 and 1986.

Reference: Figure 6.2, A Profile of the Canadian Highway System 1987. (ADI Ltd) Transport Canada. 1989 TP 8921

FIGURE A.3
OPERATING COSTS

Item	Value and Source
Fuel	
Auto & Straight Truck	$.268/L regular unleaded excl. taxes
Combination Vehicle	$.299/L diesel (commercial rate) excl. taxes
	Source: Energy Mines & Resources Oil Pricing and Market Analysis Division Feb 14/89, National survey
Oil	$2.75/L (ADI estimate)
Tires	
Auto	$102 (radial P205/75R14)
Straight Truck	
–new	$117 (radial 8.00x16.5)
–retread	$76 (with exchange)
–new+1.5 retread	$231
Combination Vehicle	
–new	$364 (radial 11x22.5)
–retread	$123 (with exchange)
–new+2.5 retread	$672
	Prices exclude federal and provincial sales tax. Based on local survey of prices Feb/89
Maintenance	
Auto	$10.60/1000km Source: "Car Costs 1987–88" Prepared by Runzheimer Canada Inc. for the Canadian Automobile Association
Straight Truck	$160/1000km Avg. for dry freight and bulk, 80,000km/yr, gasoline powered, 2–axle. Source: "Truck Costs in Canada 1988" Prepared by Trimac Consulting Services for Transport Canada. Includes repairs, cleaning and miscellaneous transport.
Tractor Trailer	$241/1000km Avg. for dry freight and bulk, 160,000km/yr, diesel powered, 5–axle and 7–axle. Source: as above

FIGURE A.4

DEPRECIATION VALUES OF VEHICLES

ITEM	Value and Source			
	Tractor	Trailer	Straight Truck	Auto
a) Avg. new price	$108,600(1)	$43,000(1)	$65,800(1)	$15,200(2)
b) Avg. depreciated value (60% of new)	65,160	25,980	38,880	9,120
c) Less tires	10 @ 364 = $3640	8 @ 364 = $2912	6 @ 117 = $702	4 @ 102 = $408
d) Less 10% salvage	10,860	4,300	6,480	1,520
e) Less federal tax(3)	0	0	0	1824
f) Net depreciable value b−(c+d+e)	50,700	18,800	31,700	5,370

(1)"1988 Truck Costs in Canada"
Avg. for 5-axle tractor
(2)"New Motor Vehicle Sales Sept/88"
Statistics Canada cat.63-007
Avg. 1988 N. American Car
(3) Vehicles over 7250 kg GVW are exempt
Automobiles 12% FST

TABLE A.5 : VALUE OF TIME

Item	Value and Source
Commercial (Straight truck or combination)	$17.32/hr Weighted avg. for private and for hire drivers + 25% fringe benefits & payroll costs Private / For Hire Avg. Wage: $26,695 / $28,390 # of Employees: 65,000 / 98,000 average hours/wk: 38 Source: Statistics Canada cat. 53–222 "1986 Trucking Costs in Canada" Statistics Canada cat. 72–002 Oct/88 "Employment Earnings and Hours"
Automobile (work)	$13.64/hr Based on Oct/88 industrial aggregate of $470.99 /wk and average of salary employees 38.8 hr/wk and hourly employees 32.1 hr/wk (avg = 34.4 hr/wk) Average varies from a high of $466.80 in Ontario to a low of $381.14 in P.E.I. Source: Statistics Canada cat. 72–002 Oct/88 "Employment Earnings and Hours"
Automobile (non–work)	$3.41/hr Based on 25% of work trip value
Split	Work/Non work = 50/50
Vehicle Occupancy	Commercial = 1.1 Auto = 1.8
Value of Time By Vehicle Type	
	Auto = avg. occ. x avg. rate = 1.8 x (13.64 + 3.41)/ 2 = $15.35/veh–hr Commercial = occupancy x rate = 1.1 x 17.32 = $19.05/veh–hr Source: Provincial Surveys; NB, Ont, Sask, Alta, BC

FIGURE A.6
ACCIDENT COSTS

Item	Value	
Minimum Average Cost per Accident:	10% discount rate with 2% per annum increase in productivity	5% discount rate 2% per annum increase in productivity
Fatal Accident	$ 368,000	$ 690,000
Injury Accident	$ 11,500	$ 11,500
Property Damage Accident	$ 3,000	$ 3,000
	Source: Lawson J.J.,"The Costs of Road Accidents and Their Application in Economic Evaluations of Safety Programs" Transport Canada, 1978 Adjusted from 1976 values to 1989 using CPI (1989$=2.3x1976$)	
Accident Rates	HUBAM default values	

NOTE: U.S. DOT National Highway Traffic Safety Administration in the report "The Economic Cost To Society of Motor Vehicle Accidents 1986 Addendum", estimate the total cost of a fatality at U.S. $358,310. This is based on a 7% discount rate and a productivity gain of 1.5% per annum. Adjusting for Canadian dollars (24 cents), number of fatalities per fatal accident ($1.19) and CPI increases 1986 to 1989 ($1.12) the cost comparable to the values shown above is $568,000. Given the difference in discount rates, this value closely approximates the above estimated values.

FIGURE A.7

HIGHWAY MAINTENANCE COSTS
(1989 $)

Surface Type	Description	Maintenance Cost ($/Lane-Km)	
		Annual	Periodic
Paved	Freeway	$1,719	$104,180
	Multi-lane divided	$1,771	$65,113
	Multi-lane undivided	$1,745	$58,602
	Two-lane	$1,706	$32,556
Gravel	Well maintained	$1,302	$3,256
	Poorly Maintained	$651	$5,209

Source: HUBAM model updated from 1983 @4.5% per annum

APPENDIX B

NATIONAL HIGHWAY POLICY
DESIGN STANDARDS AND GUIDELINES

APPENDIX B

NATIONAL HIGHWAY POLICY STUDY
Design Standards & Guidelines

Design of Control Element	Guideline or Desired Objective
A.	**Geometric Design**
1.	Access Control Complete access control is desired objective for all freeways, limited access is objective for all other road types.
2.	Design Speed Two Lane Highways Mountainous Terrain - minimum 90 km/h Rolling and Flat Terrain - minimum 100 km/h Four or More Lane Mountainous Terrain - minimum 100 km/h Rolling Terrain - minimum 110 km/h Flat Terrain - minimum 120 km/h
3.	Lane Width Minimum 3.7 meters
4.	Shoulder Width Two Lane Highways Minimum 3.0 meters of which a minimum of 0.8 meters is paved Four or More Lane Highways Right Shoulder Minimum 3.0 meters of which a minimum of 0.8 meters is paved Left Shoulder Minimum 1.5 meters of which a minimum of 0.8 meters is paved
5.	Median Width (divided highways) Without Barrier Protection Minimum 20 meters (edgeline to edgeline) With Barrier Protection Minimum 6.0 meters (edgeline to edgeline)
6.	Right of Way Minimum based on future upgrading to meet standards

Design of Control Element	Guideline or Desired Objective
7.	Horizontal Clearance Minimum of 10 meters on both sides, unless barrier protection is provided
8.	Vertical Clearance Minimum of 5.0 meters including shoulders
9.	Design Load Minimum based on national standards for vehicle weights and dimensions, all weather operation with no seasonal load restrictions
B.	**Bridges and Overpasses**
1.	Design Loads Minimum based on national standards for vehicle weights and dimensions
2.	Vertical Clearance Minimum 5.0 meters, including shoulders
3.	Width As specified in Manual of Geometric Design Standards for Canadian Roads
C.	**Other Design and Control Elements**
1.	Traffic Control Devices As specified in the Manual on Uniform Traffic Control Devices for Canada
2.	Signing and Pavement Marking As specified in the Manual on Uniform Traffic Control Devices for Canada
3.	Rest Areas Public or private rest areas should be available or provided at approximately two hour driving intervals along the system
4.	Commercial Signing Private commercial signing should not be permitted within the right of way
5.	Illumination Minimum standards as described in the TAC Illumination Manual
6.	Overhead Utility Clearance Minimum standards as required or recommended by utility authorities

APPENDIX C

SAMPLE CALCULATIONS FOR SENSITIVITY ANALYSIS

Value of Auto time increases by 50%

Let the ratio of Auto time savings to Heavy vehicle time savings be a/b

- **Baseline parameters**

Value of time for Auto = \$8.52/hr based on 50/50 work/non-work split
Value of time for Heavy vehicles = \$17.32/hr

Baseline time savings = 8.52a + 17.32b ♦

- **Sensitivity case**

Value of time for Auto = \$12.78/hr based on 50/50 work/non-work split
Value of time for Heavy vehicles = \$17.32/hr

Sensitivity case time savings = 12.78a + 17.32b ♦

- **Multiplying factor**

Multiplying factor
= Sensitivity case time savings/Baseline time savings
= (12.78a + 17.32b)/(8.52a+17.32b)

Based on a 87/13 split for a/b as determined from Figure A.2 in Appendix A, the multiplying factor turns out to be 1.40 ♦

Value of Auto time decreases by 50%

Using similar calculations as above, the multiplying factor is calculated to be 0.60 ♦

Unit cost of fatal accident increases to $1.4M

ASSUME that a proposed improvement leads to a safety saving of 100 accidents. Accordingly, the baseline accident saving and the sensitivity case accident saving can be calculated as shown below.

- **Baseline parameters**

Unit cost of fatal accident = $368,000
Unit cost of injury accident = $11,500
Unit cost of property damage accident = $3,000
Accident distribution : 3% fatal, 34% injury, 63% property damage

Baseline accident savings = 3(368,000) + 34(11,500) + 63(3,000) = $1,684,000 ♦

- **Sensitivity case**

Unit cost of fatal accident = $1,400,000
Other parameters remain unchanged

Sensitivity accident savings = 3(1,400,000) + 34(11,500) + 63(3,000) = $4,780,000 ♦

- **Multiplying factor**

Multiplying factor = 4,780,000/1,684,000 = 2.84 ♦

Unit cost of fatal accident increases to $2.5M

Using similar calculations as above, the multiplying factor is calculated to be 4.80 ♦